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MONITORING RESULTS OF NORTHERN GOSHAWK NESTING AREAS IN THE GREATER YELLOWSTONE ECOSYSTEM: IS DECLINE IN OCCUPANCY RELATED TO HABITAT CHANGE?

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Abstract.—I monitored a subset of Northern Goshawk (*Accipiter gentilis*) nesting areas on the Targhee portion of the Caribou-Targhee National Forest in eastern Idaho and western Wyoming from 1998–2002 (recent period) to provide occupancy and productivity data for U.S. Forest Service monitoring requirements. A total of 16 randomly-selected nesting areas, half in undisturbed and half in timber-sale project areas, were surveyed each year. Occupancy in 1998–2002 averaged 34%, which was significantly lower than the 61% measured at these nesting areas from 1992–95 (baseline period) using similar survey methods and effort. Productivity of successful nests was similar between the two periods. I used the dawn vocalization survey method in 2001–02, in addition to standard broadcast survey methods, to determine if low occupancy reflected a poor detection rate of pairs that occupied sites, but failed to reproduce. Detection rate of goshawks during the courtship period in these 2 yr averaged less than 50%, indicating that number of pairs reoccupying known nesting areas surveyed was low. I found no relation between weather factors and lower occupancy. Occupancy at nesting areas located in past timber-harvest areas in the recent period was significantly lower compared to those in less disturbed habitat (22% occupancy versus 45%, respectively) suggesting that occupancy may be influenced by the long-term effects of timber-management practices. Whether the observed decline during the recent period reflects spatial shifts of nesting pairs, short-term demographic responses to variation in weather or prey, or longer-term responses to changes in forest structure and age resulting from timber-management activities, cannot be determined using the current monitoring program. Long-term monitoring of study areas in the western United States, based on statistically valid study designs and adequate sample size, is needed to understand if the apparent decline in goshawk occupancy reported here and in other recent studies has serious implications for conservation of this species.

Key Words: *Northern Goshawk;* Accipiter gentilis; *nest-site occupancy; raptor monitoring; survey techniques; forest management.*

RESULTADOS DEL MONITOREO DE ÁREAS DE NIDIFICACIÓN DE *ACCIPITER GENTILIS* EN EL AMPLIO ECOSISTEMA DE YELLOWSTONE: ¿ESTA RELACIONADA LA DISMINUCIÓN EN LA OCUPACIÓN CON EL CAMBIO DEL HÁBITAT?

Resumen.—Evalué un conjunto de áreas de nidificación de *Accipiter gentilis* en la porción Targhee del Bosque Nacional de Caribou-Targhee en el este de Idaho y oeste de Wyoming desde 1998 hasta 2002 (período actual) para proveer datos de ocupación y productividad para los requerimientos de evaluación del Servicio Forestal. Un total de 16 áreas de nidificación seleccionadas al azar fueron evaluadas cada año (la mitad en áreas no perturbadas y la mitad en áreas de proyectos de venta de madera). La ocupación promedio durante el período actual fue de un 34%, lo cual fue significativamente menor que el 61% medido en áreas de nidificación desde 1992 hasta 1995 (período de línea de base) usando métodos y esfuerzos de muestreo similares. La productividad de los nidos exitosos fue similar entre los dos períodos. Realicé muestreos de vocalizaciones durante el amanecer en 2001 y 2002, además de otros métodos estándar de reproducción de grabaciones, para determinar si la baja ocupación reflejaba una tasa de detección baja de las parejas que ocupaban los sitios pero que no se reproducían. La tasa de detección de *A. gentilis* durante el período de cortejo en estos dos años fue en promedio menos del 50%, indicando que el número de parejas que ocuparon nuevamente las áreas conocidas de nidificación fue bajo. No encontré una relación entre los factores climáticos y una baja ocupación de individuos. La ocupación durante el período actual en las áreas de nidificación en las que se cosechó madera en el pasado fue significativamente menor comparada con la de ambientes menos perturbados (22% de

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presencia comparado con 45%, respectivamente), sugiriendo que la ocupación podría estar asociada con los efectos de largo plazo de las prácticas de manejo forestal. Usando el plan actual de evaluación, no es posible determinar si la disminución observada durante el período actual refleja desplazamientos espaciales de parejas nidificantes, respuestas demográficas de corto plazo a la variación en el clima o las presas, o respuestas de largo plazo a los cambios en la estructura del bosque y en las clases de edad resultantes de las actividades de manejo forestal. Es necesaria una evaluación a largo plazo de las áreas de estudio en el oeste de los Estados Unidos, basada en estudios con diseños estadísticamente válidos y tamaños de muestreo adecuados, para entender si la disminución aparente en la ocupación de *A. gentilis* presentada aquí y en otros estudios recientes tiene implicancias serias para la conservación de esta especie.

[Traducción del Equipo Editorial]

Concern over potential effects of forest management on Northern Goshawk (*Accipiter gentilis*) populations nesting in western North America has stimulated research on this species since the early 1970s (Squires and Reynolds 1997). The U.S. Forest Service (USFS) controls a large proportion of forested lands in the western United States, and how forest habitat is managed on these lands has been a primary focus of past goshawk research (Reynolds 1983, Crocker-Bedford 1990, Reynolds et al. 1992). The goshawk is classified as a Sensitive Species and a Management Indicator Species for forested habitats on the Caribou-Targhee National Forest (CTNF) where this study was conducted (USDA 1997a). The USFS is required to monitor goshawk population trend and its relationship to habitat change for designated Management Indicator Species by federal regulations resulting from implementation of the National Forest Management Act of 1982.

Little information existed on goshawk nesting ecology or habitat on the CTNF prior to the 1990s. From 1989–95, I conducted surveys and collected data on demographic and habitat parameters at four historic and 27 occupied nesting areas located in a variety of habitats and management areas across the forest (Patla 1997). In 1997, the CTNF adopted a revised Land Management Plan (LMP) that required monitoring a minimum of 15 randomly-selected nesting areas for adult occupancy each year as an indicator of population trend (USDA 1997b). I conducted these surveys annually for occupancy and productivity from 1998–2002. To provide some insight on potential associations between timber harvest and resultant habitat change on goshawk demographics, I selected 16 nesting areas each year: half located within past timber-sale project areas and half from relatively undisturbed areas.

The objectives of this study were: (1) to compare demographic data collected from 1998–2002 (recent period) to comparable data collected during a baseline-study period from 1989–95, as an indication of population trend of known nesting areas, (2) to compare demographic data collected at nesting areas in relatively undisturbed habitat to those in timber-harvest management areas to examine if goshawk occupancy patterns changed related to timber-harvest activities, (3) to provide information on survey methods and results including a description of a dawn-vocalization survey, and (4) to discuss implications of this study and the need to improve monitoring efforts in study areas in the Intermountain West.

STUDY AREA

The Targhee portion of the CTNF contains ca. 728 000 ha in eastern Idaho and western Wyoming and comprises the western portion of the Greater Yellowstone Ecosystem (GYE) as described by Clark and Zaunbrecher (1987; Fig. 1). Most of the CTNF falls within the Middle Rocky Mountain physiographic province except for a small portion, which is included in the Northern Rocky Mountain Province (Steele et al. 1983). Elevations range from 1585–3470 m. The climate is characterized by long, cold winters with heavy snowfall and mild, dry summers. Mean temperatures are −8° and 18°C for January and July, respectively, and total annual precipitation ranges between 61 and 102 cm (Patla 1997).

Douglas-fir (*Pseudotsuga menziesii* var. *glauca*) and lodgepole pine (*Pinus contorta*) are the most common conifer species within the montane zone, between 1800–2500 m (Habeck 1994), and are the primary commercial tree species harvested on the forest. The dominant cover type at 31 goshawk nesting areas within a radius of 2428 ha centered at known nest trees was Douglas-fir ($N = 14$), mixed conifer ($N = 9$), and lodgepole pine ($N = 8$; Patla 1997). I found the majority of goshawk nests ($N = 49$) in mature Douglas-fir (78%) and lodgepole pine (8%) trees. Mean age of Douglas-fir and lodgepole pine trees used for nesting was 143 yr and 96 yr, respectively.

The CTNF initiated a commercial timber sale program in the early 1960s, and an estimated 1935 million board feet (MBF) of mature timber was harvested from 1963–2001 (Fig. 2; M. Jenkins, CTNF Silviculturist, unpubl. data). The mean annual harvest was 62.0 MBF (1963–92)

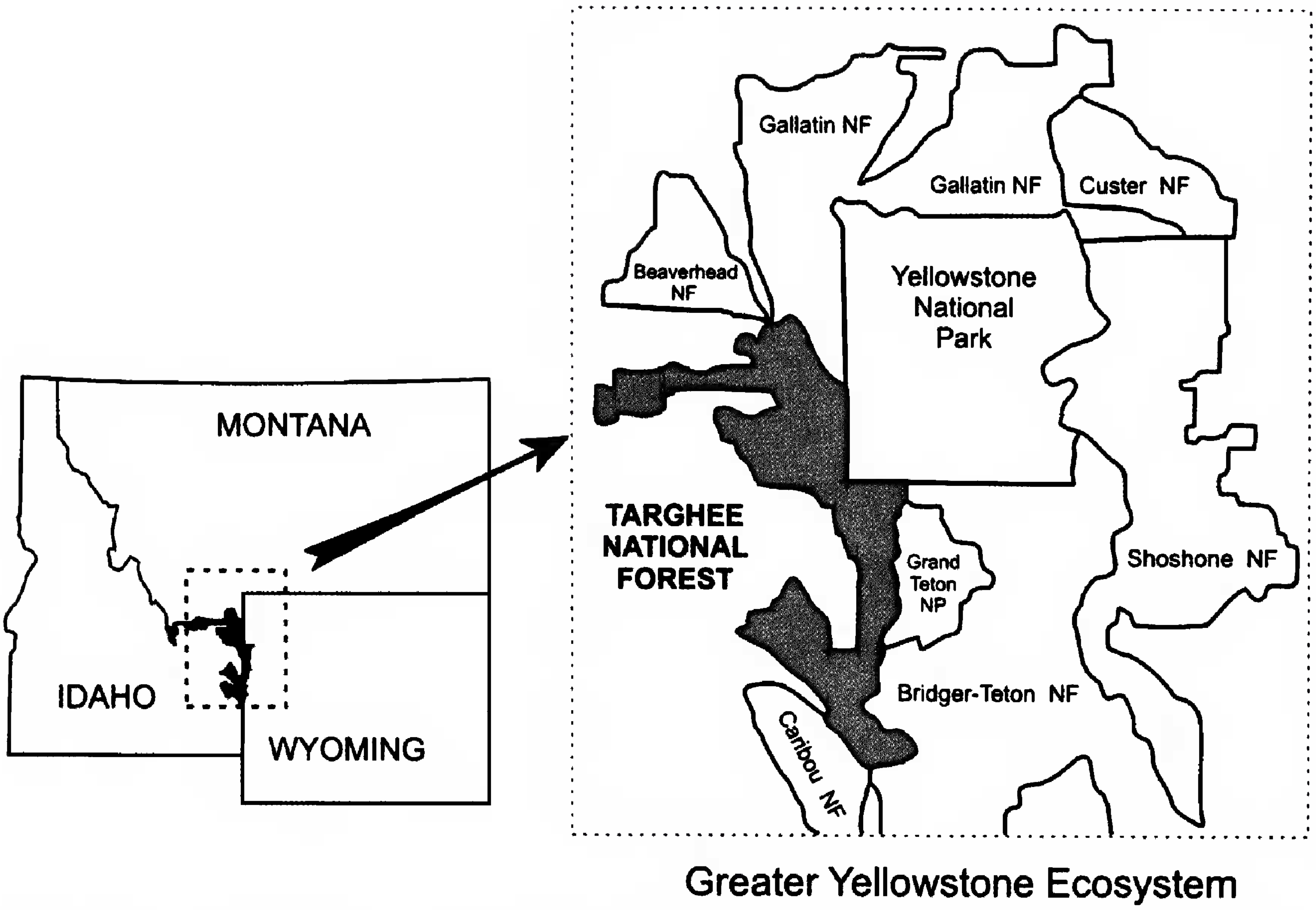

Figure 1. Location of the study area of the Caribou-Targhee National Forest in the Greater Yellowstone Ecosystem in relation to adjacent national forests and parks.

but dropped to 8.2 MBF in recent years (1993–2001). Harvest methods included clear-cutting of lodgepole pine and seed tree or shelterwood cuts of Douglas-fir (Patla 1997). No large-scale timber harvesting projects occurred in the vicinity of known goshawk nesting areas during the current study period.

The revised 1997 CTNF Land Management Plan manages goshawk nesting habitat by specifying the level, type, and timing of management activities that can be conducted at different spatial areas surrounding historical and current nesting areas (USDA 1997b). Prior to the late 1990s, a few occupied goshawk nests found in timber sale units were protected by creation of small buffers (a few trees up to 4 ha; Patla 1997). The majority of harvesting occurred on the CTNF prior to the implementation of goshawk monitoring protocols.

METHODS

Sampling Unit and Scheme. The sampling unit monitored in during the recent period, 1998–2002, was the *nesting area* which included all known nests used by a pair of goshawks and the surrounding area of 1.6 km radius measured from a centroid based on known nest locations (Woodbridge and Detrich 1994, Siders and Kennedy 1996). The size of the defined nesting area (2428 ha) was based on known nearest-neighbor distance data and territory spacing measured in this study area and others in the western United States and should be sufficient to distinguish between nesting pairs (Reynolds et. al. 1994, Woodbridge and Detrich 1994, Patla 1997).

I monitored 16 nesting areas each year, randomly selected from a master list of 34, that had been occupied by a pair of goshawks at least once since 1989. I excluded from the selection process a few nesting areas in difficult to access locations, and also some historical nesting areas occupied prior to 1989 in which harvesting had subsequently eliminated known nest stands, and where I had found no evidence of goshawk use during the baseline study (1989–95). Prior to selecting monitoring sites, I classified the 34 nesting areas into one of two categories: (1) undisturbed sites located outside of the boundaries of timber-management project areas ($N = 15$) with little or no harvesting within the defined nesting area, or (2) timber-harvest sites ($N = 19$). Eight nesting areas from each category were monitored each year 1998–2002.

I included in the timber-harvest category all goshawk nesting areas with nest sites that fell within the boundaries of past timber sale projects. Thus, timber-harvest sites included a range of disturbance conditions. I did not quantify differences between undisturbed and timber-harvest sites as a detailed vegetation analysis of nesting areas was beyond the scope of the current study.

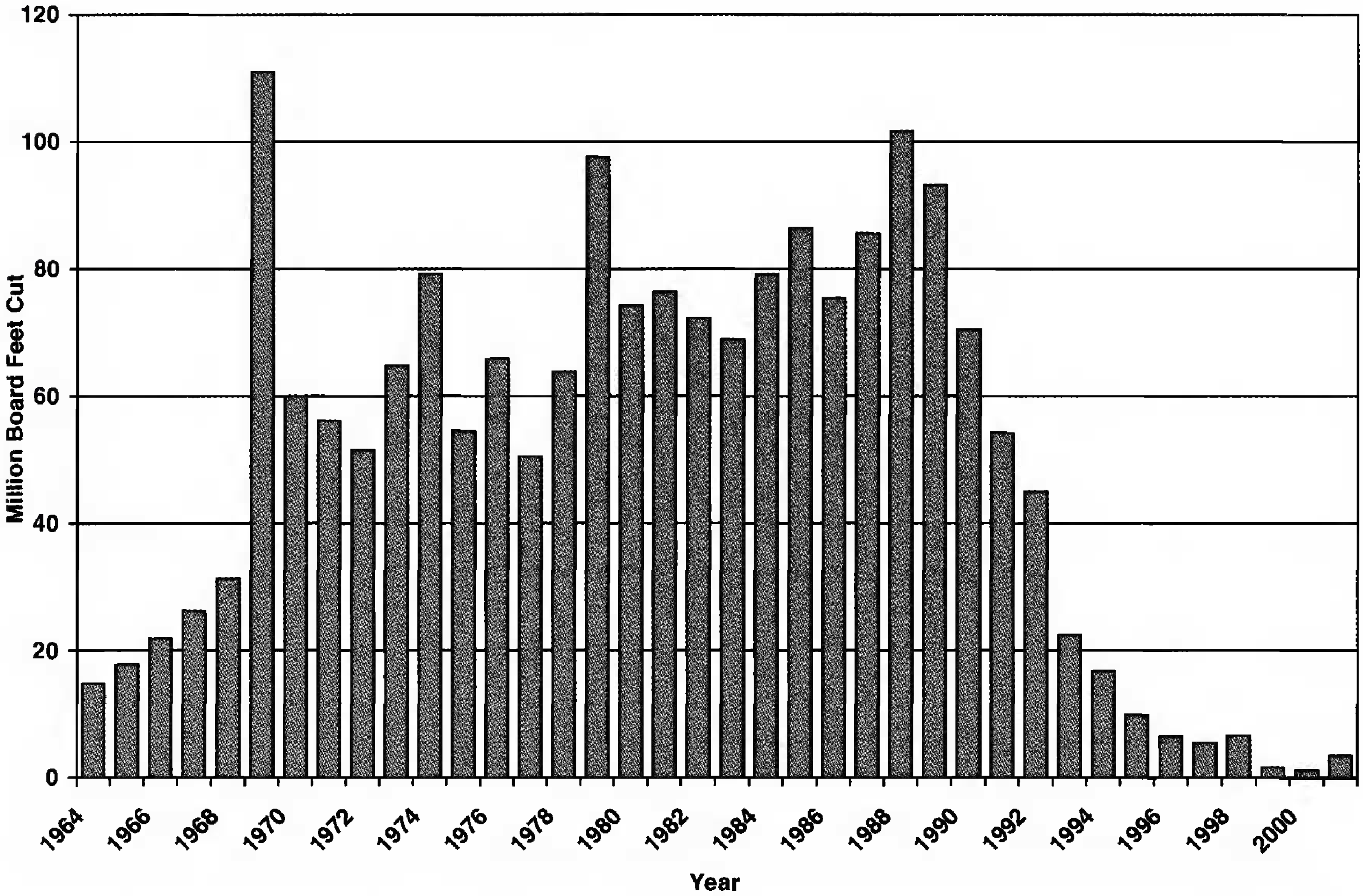

Figure 2. Timber harvest activity on the Targhee section of the Caribou-Targhee National Forest showing volume cut in million board feet per year, 1964–2002. Northern Goshawk monitoring was initiated in 1989.

Based on previous analysis of ten nesting areas found in timber-sale project areas and subsequently harvested between 1985–92, harvesting resulted in a reduction in mature forest cover within the defined nesting area (Patla 1997). Prior to harvest, mature forest habitat averaged 80% (range = 63–95%) within the nesting area compared to 61% (range = 51–80%) post-harvest. Reduction of forest habitat was greatest in the center of the nesting area (see Patla 1997).

To compare monitoring results from the recent period to the baseline period, I first removed data for baseline sites not surveyed at the same spatial scale using the broadcast survey method (see Patla 1997 for description of baseline survey methods). I then made a random selection of 16 sites from those years, 1992–95, for which I had a sample pool greater than 16 that met sampling criteria. I did not include results from 1990–91 due to inadequate number of nesting areas and from 1996–97 because I did not monitor nesting goshawks during these years.

Monitoring Terms. I considered a nesting area occupied if: (1) a pair was observed vocalizing, copulating, or nest building in the vicinity of known nests, or a single adult was heard vocalizing in the vicinity of a known nest tree during the pre-nesting period on more than one day (mid-March–early May), (2) a single adult or pair defended a nest site during the incubation/nestling period, or evidence of nest building or egg laying was confirmed (late April–early June), or (3) young of the year were found during the nestling (June–mid-July) or fledgling periods (July–mid-August; Postupalsky 1973, Steenhof 1987, Woodbridge and Detrich 1994). I classified a nesting area as not occupied if a single adult was heard making a few calls on only one day during the courtship period, or if an adult was seen on a single occasion later in the season, and no additional signs of goshawk presence were detected within the 1.6-km radius survey area. I classified a pair as having laid eggs and attempted to nest when an adult was found incubating or young were observed in the nest (Postupalsky 1973). Nests were classified as successful if at least one fledgling or fully-feathered nestling (ca. 5-wk post hatching) was observed. Each year that a nesting area was monitored was considered a territory year for calculating occupancy rates (Woodbridge and Detrich 1994).

Survey Methods. I based timing of surveys in the recent period on nesting chronology calculated from 37 successful nest attempts, 1989–94 (Patla 1997). I used similar survey methods during both time periods. The mean onset of incubation was 5 May (range = 20 April–20 May), mean hatching date was 6 June (range = 22 May–June 21), and the mean fledge date was 15 July (range = 1 July–3 August).

All known nest trees and stands were checked visually in April or May for goshawk activity (e.g., fecal deposits, molted feathers, conifer sprigs on nests). If pairs were not detected, standardized broadcast calling surveys (Kennedy and Stahlecker 1993, Joy et al. 1994) were conducted in forest habitat within a 0.8-km radius of the last used nest during the nestling period (early June–mid-July). Survey effort was expanded in the fledgling period (mid-July–end of August), if no detections were obtained on earlier surveys, to cover a 1.6-km radius area based on a centroid of known nests. Transect lines were 260 m apart, and calling stations ranged from 150–300 m, depending upon terrain and density of forest cover. Surveys were not conducted on days when wind or rain interfered with the ability to transmit calls or hear detections. Occupied nests were monitored every 2 wk to determine number of young and approximate fledging date.

In 2001 and 2002, in addition to broadcast surveys during the nestling and fledgling periods, I surveyed all selected nesting areas using the dawn vocalization survey method to increase the likelihood of detecting pairs that abandoned the nesting effort early in the season, prior to egg laying or incubation (Penteriani 1999, Dewey et al. 2003). Observation points were selected within 100–200 m from the last nest tree occupied, or centered between clusters of alternate nest trees located within a few hundred meters of each other. At nesting areas with nests located >200 m apart, either two observers stationed within 100–200 m of known nests were used, or a single observer completed surveys on different days. Observation periods lasted for a minimum of 2 hr starting 30–45 min prior to sunrise and ending 1.5–2 hr after sunrise. If no goshawk activity was detected during the initial survey, follow-up surveys were conducted 1–3 wk later, if possible.

Statistical Analysis. To compare demographic results between the baseline and recent monitoring periods, and undisturbed and timber harvest nesting areas in the recent monitoring period, I treated the 16 nesting areas selected each year as independent samples.

For most statistical analyses, I applied a multi-response permutation process (MRPP) that is analogous to one-way analysis of variance (or t-test), using *Blossom* software (Cade and Richards 2001). MRPP statistical procedures have no distribution assumptions and work well for ecological data with small sample sizes that lack normal distribution even after data transformations (Cade and Richards 2001). I used the chi-square contingency test to compare number of occupied nesting areas in undisturbed and timber sale areas in the recent period. Significance level for all tests was $P = 0.05$.

Analysis of Weather Parameters. Weather factors have been shown to influence occupancy of goshawk nests (Kostrzewa and Kostrzewa 1991, Patla 1997). To analyze potential effects of drought, I compared total annual precipitation between the baseline and recent periods including the year prior to each defined time segment based on precipitation measured at Driggs, ID (Climate Station No. 2676, Teton County, elevation 1866 m) near the center of the study area (Idaho State Climate Services 2002). I also compared snow water equivalents (SWE) in March between the baseline and recent periods (Pine Creek Pass, Climate Snow Station No. 6720, Teton County, elevation 2049 m) (Idaho State Climate Services 2002). SWE is computed from snow density to determine percent water content in the snow pack.

RESULTS

Survey Effort. Eighty territory-year checks were completed (16 nesting areas monitored/yr) during the current monitoring period. Thirty of the 34 nesting areas (88%) on the master list were monitored at least once. Sampling frequency ranged from 0–5 yr ($\bar{x} = 2.4$ yr) for individual nesting areas.

Observers visited nesting areas on average 5.7 ± 0.87 (SD) times per breeding season. At nesting areas where no occupied nests or young were detected, observer effort averaged 64 ± 18 (SD) calling stations, and 15.9 ± 7.9 hr/territory in suitable habitat. Similar effort was expended during 1992–95 with calling stations played within a 1.6-km radius at similar intervals using the same protocol.

Occupancy and Productivity. The mean occupancy rate in the recent period was 34% and was significantly lower compared to the baseline period (61%; MRPP: $P = 0.031$; Table 1). Occupancy rate was highest in 1992 and then declined in subsequent years (Table 1, Fig. 3).

In the current monitoring period, 20% of nesting areas had successful nests and produced a total of 35 young (Table 1). Nest success and total number of young produced was significantly higher (MRPP: $P = 0.003$ and $P = 0.004$) during 1992–95 (Table 1). However, mean number of young per nesting pair and per successful nest was nearly identical between the two study periods (Table 1).

Weather Analysis. I found no significant difference in two weather factors analyzed that might have influenced comparative occupancy rates. Mean annual precipitation was similar between the 1992–95 period (30.9 ± 3.5 cm) and recent period (1996–2002; 36.6 ± 7.1 cm; MRPP, $P = 0.109$). March SWE was also similar: 32% in 1992–95 compared to 33% in 1996–2002 period (MRPP, $P = 0.928$).

Undisturbed Versus Timber-harvest Nesting Areas. In the recent period (1998–2002), a significantly greater number of undisturbed nesting areas (18/40 = 45 ± 14%) compared to timber-harvest nesting areas (9/40 = 22.5 ± 10%) were occupied (χ^2, $P = 0.033$; Table 2). Pairs in undisturbed nesting areas produced a greater number of young per yr (Table 2, MRPP: $P = 0.027$). The mean number of young produced per nesting pair and per successful territory was similar (Table 2).

Mean occupancy rates during the 1996–2002 monitoring period at both undisturbed (45.0%)

Table 1. Summary of monitoring data from 16 randomly-selected Northern Goshawk nesting areas by year on the Caribou-Targhee National Forest, comparing the current period (1998–2002) to baseline data collected 1992–95. Nesting and success rates are based on total number of nest areas surveyed.

Year	Nesting Areas Occupied	Nesting Pairs	Pairs with Fledglings	Total Number of Young	Occupancy Rate (%)	Nesting Rate (%)	Success Rate (%)	Young per Occupied Nest Area	Young per Nesting Pair	Young per Successful Nest Area
	(N = 16)									
1992	15	15	12	25	0.94	0.94	0.75	1.67	1.67	2.08
1993	8	8	7	12	0.50	0.50	0.44	1.50	1.50	1.71
1994	7	7	7	19	0.44	0.44	0.44	2.71	2.71	2.71
1995	9	9	6	13	0.56	0.56	0.38	1.44	1.44	2.17
Mean	9.8	9.8	8.0	17.3	0.61	0.61	0.50	1.83	1.83	2.17
(SD)	(4.4)	(4.4)	(2.9)	(6.5)	(0.27)	(0.27)	(0.18)	(0.60)	(0.60)	(0.41)
Recent	(N = 16)									
1998	4	4	4	10	0.25	0.25	0.25	2.50	2.50	2.50
1999	5	5	1	2	0.31	0.31	0.06	0.40	0.40	2.00
2000	5	4	4	9	0.31	0.25	0.25	1.80	2.25	2.25
2001	7	4	4	9	0.44	0.25	0.25	1.29	2.25	2.25
2002	6	3	3	5	0.38	0.19	0.19	0.83	1.67	1.67
Mean	5.4	4.0	3.2	7.0	0.34	0.25	0.20	1.36	1.81	2.13
(SD)	(1.1)	(0.7)	(1.3)	(3.4)	(0.07)	(0.04)	(0.08)	(0.82)	(0.85)	(0.32)

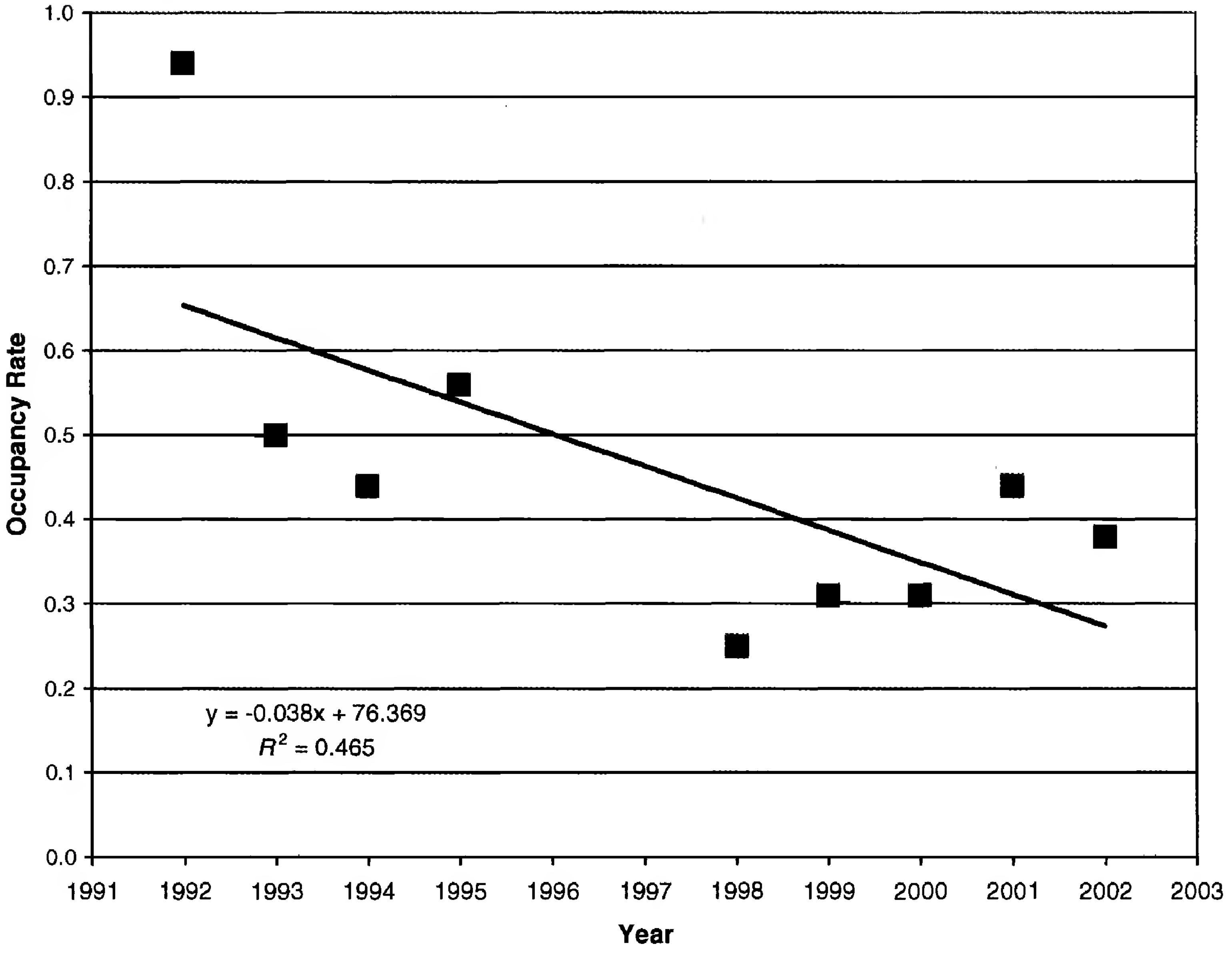

Figure 3. Regression analysis of occupancy rate 1992–2002 of Northern Goshawk nesting areas on the Caribou-Targhee National Forest. Data not available for years 1996 and 1997.

and timber-harvest nesting areas (22.5%) were lower compared to the 61% mean occupancy rate measured 1992–95 (Table 1). The observed decline in the recent period was over twice as high in timber-harvest nesting areas (63%) compared to undisturbed nesting areas (26%).

Use and Spacing of Alternate Nest Trees. Of 18 nest attempts documented from 1996–2002, only three (17%) occurred in previously identified nest trees. Eighty percent (N = 12) of new alternate nest trees found were located within 800 m of the last nest tree used. Mean distance between alternate nest trees used within a nesting area was 572 ± 352 m, (range = 77–1381 m, N = 15). I found no relationship in the distance between nest trees used and the span of years since goshawks had been documented nesting in a particular area (Pearson correlation, r = 0.009, P = 0.975). Nest trees tended to be clustered within the defined nesting areas.

Goshawk Detections and the Dawn Survey Method. The majority of initial detections confirming occupancy of nesting areas (63%, 17/27) occurred during the courtship period compared to 26% in the nestling (N = 7) and 11% in the fledgling periods (N = 3). Most detections in the courtship period (71%) were obtained using the dawn vocalization survey method in 2001–02, which resulted in detections of pairs or single adults at 15 sites (Table 3).

Number of dawn surveys completed averaged 3.0 per nesting area in 2001 (range = 1–5) and 1.9 (range = 1–3) in 2002. During these two years, 92% of all nesting areas confirmed occupied resulted from use of dawn surveys with only one false negative at a site where an occupied nest was found later in the fledgling period 655 m from the last used nest tree. At three sites, detections were documented only on one day, with no other goshawk activity being observed during the remainder of the nesting season. I did not classify these nesting areas as occupied (Table 3) given the brevity of the

Table 2. Comparison of monitoring data from randomly-selected Northern Goshawk nesting areas in undisturbed and past timber-harvest areas, Caribou-Targhee National Forest (1998–2002).

YEAR	OCCUPIED NESTING AREA	NESTING PAIRS	SUCCESSFUL PAIRS	TOTAL NUMBER OF YOUNG	YOUNG PER OCCUPIED NEST AREA	YOUNG PER NESTING PAIR	YOUNG PER SUCCESSFUL NEST AREA
Undisturbed	(N = 8/yr)						
1998	3	3	3	7	2.33	2.33	2.33
1999	2	0	0	0	0.00	0.00	0.00
2000	4	3	3	7	1.75	2.33	2.33
2001	5	3	3	8	1.60	2.67	2.67
2002	4	2	2	4	1.00	2.00	2.00
Mean	3.6	2.6	2.2	5.2	1.34	1.87	1.87
(SD)	(1.1)	(0.5)	(1.3)	(3.3)	(0.9)	(1.1)	(1.1)
Timber-harvest	(N = 8/yr)						
1998	1	1	1	3	3.00	3.00	3.00
1999	3	3	1	2	0.67	0.67	2.00
2000	1	1	1	2	2.00	2.00	2.00
2001	2	1	1	1	0.50	1.00	1.00
2002	2	1	1	1	0.50	1.00	1.00
Mean	1.8	1.4	1.0	1.8	1.33	1.53	1.80
(SD)	(0.8)	(0.9)	(0.0)	(0.8)	(1.10)	(1.00)	(0.80)

vocalizations and lack of other evidence confirming occupancy. Without use of the dawn survey method, 43% of nesting areas in 2001 (N = 3) and 33% in 2002 (N = 2) would not have been classified as occupied. However, even with use of courtship surveys, occupancy of nesting areas during these two years fell below the 61% average from 1992–95 (Table 1). Occupancy in 2001, the highest occupancy year during 1996–2002, was the same (44%) as 1994, the lowest occupancy year from 1992–95. Even if goshawk pairs or individuals were detected during the courtship period, follow-up broadcast calling surveys were required at many sites later in the season to locate an occupied nest tree and determine number of young.

DISCUSSION

Monitoring Effort and Study Design. Monitoring Northern Goshawk nesting populations is challenging given the secretive nature of the species, its use of widely-spaced alternate nests, spatial and temporal variability in numbers of nesting pairs, and density of the mature forest habitat used for nesting (Woodbridge and Detrich 1994, Kennedy 1997, Squires and Reynolds 1997). Comparison of occupancy among studies is also difficult as occupancy estimates appear to be positively correlated with amount of effort expended to determine nesting area status (Kennedy 1997). Multiple visits to nesting areas over the course of a season and broadcast-calling surveys at least up to 1.6-km ra-

Table 3. Results of dawn vocalization surveys during March and April at Northern Goshawk nesting areas (N = 16/yr) on the Caribou-Targhee National Forest (2001–02).

YEAR	TOTAL NO. SURVEYS	EARLIEST DETECTION DATE	LATEST DETECTION DATE	NO. DETECTIONS[a] (OCCUPANCY)	NO. DETECTIONS SINGLE BIRD[b]	ERROR RATE[c]
2001	48	31 Mar	2 May	7 (0.44)	1	0.00
2002	30	26 Mar	20 April	5 (0.31)	2	0.06
Total	78	26 Mar	2 May	12 (0.38)	3	0.03

[a] Number of territories classified as occupied where a pair was detected or a single adult was heard or seen on more than 1 day

[b] Number of territories where detections consisted only of a few "*kek*" calls heard briefly one day.

[c] Error rate defined as the proportion of territories misclassified as unoccupied and later confirmed as occupied.

dius around nest sites are required to monitor previously identified nesting areas effectively (Reynolds et al. 1994, Woodbridge and Detrich 1994, Finn et al. 2002).

The amount of survey effort expended per nesting area (mean number of visits per site and area surveyed) for the current goshawk monitoring period matches or exceeds that reported in other long-term goshawk studies (Kennedy 1997, Boyce et al. 2005, Reynolds et al. 2005). The total number of nesting areas monitored per year was relatively low, however, and included only a subset of known areas scattered throughout the CTNF.

The goshawk-monitoring plan for the CTNF is based on the assumption that goshawks exhibit territorial behavior and that "a stable population should revolve around some average occupancy rate" of known nesting areas (USDA 1997b). The plan assumes that the occupancy measured at a subset of known nesting areas can be used as an index of population stability or decrease for the species. The plan states: "A sustained downward trend of adult occupancy for at least four years may indicate a need for action" (USDA 1997b). There are no specific requirements that monitoring protocols developed for land management plans follow statistically rigorous study design criteria. The approach to monitoring on a forest level tends to be pragmatic and based on limited funding availability. Whether the study design used on the CTNF is adequate as an index for local population trend requires further statistical evaluation. For this analysis, I assumed that occupancy results apply to the target population of known nesting areas monitored and may not reflect forest-wide population trends.

Decline in Occupancy. Results of this study indicate that occupancy of known goshawk nesting areas on the CTNF was significantly higher in the early 1990s compared to later in the decade with no rebound evident through the 2002 nesting season (Fig. 3). Results are consistent with those reported from other goshawk study areas suggesting that there may have been a decline in some goshawk populations across the Intermountain West during the late 1990s (Fairhurst and Bechard 2005, Reynolds et al. 2005).

Results from dawn vocalization surveys on the CTNF indicated that the lower occupancy measured in the recent period likely did not result from failure to detect pairs that occupied sites but did not reproduce (Woodbridge and Hargis 2005). However, it is possible, given the study design and low sample number that spatial shifts by pairs outside of areas surveyed may have confounded results. Studies of marked goshawks have shown that shifts between nesting areas by individual breeding adults occur to some extent and that some ephemeral territories are occupied only occasionally (Woodbridge and Detrich 1994, Reynolds and Joy 1998, Reynolds et al. 2005). If a proportion of pairs at study sites on the CTNF shifted each year between sites, or used certain sites only occasionally, occupancy results could be misleading.

Weather conditions can influence goshawk occupancy, but I did not find a significant difference between the recent and baseline periods in relation to total annual precipitation and snow water equivalents. The latter factor was negatively related to occupancy in the baseline study period (Patla 1997). There may be other local or regional weather/climatic trends not analyzed in this study that were influencing occupancy rates during the study period.

The amount and structure of forest habitat surrounding nest sites has been related to occupancy of historical goshawk nest sites in the western United States (Crocker-Bedford 1990, Woodbridge and Detrich 1994, Desimone 1997, Finn et al. 2002, McGrath et al. 2003). During the baseline study period, I also found an association between the proportion of mature forest habitat and occupancy rate of nesting areas on the CTNF. High occupancy nest clusters in timber harvest areas, defined as those with ≥50% occupancy rate (N = 16, $\bar{x}$ occupancy = 81%), contained a significantly greater proportion of mature forest cover and less young forest/seedling cover within a 240 ha area surrounding known nests compared to low occupancy nest clusters (N = 6, occupancy = 37%; Patla 1997).

In the recent study period, occupancy of nesting areas on the CTNF in timber-harvest areas showed a greater proportional decline than those in less disturbed habitat, but vegetation differences between these categories were not quantified. There appears to be an association between reduction in mature forest habitat within nesting areas on the CTNF as a result of harvesting and decline in occupancy. This hypothesis requires further investigation of vegetation conditions at nest areas in relation to goshawk occupancy patterns.

In contrast to occupancy data, I found no difference in productivity of nesting goshawk pairs between the baseline and recent periods or between timber harvest and undisturbed sites in the recent period. Pairs that nested successfully produced similar number of young supporting the suggestion by McClaren et al. (2002) that number of young fledged may not be useful for assessing spatial variability in goshawk nest habitat quality.

Whether the decline in occupancy measured at known nesting areas on the CTNF reflects a response to decline in quality of primary habitat, a shorter-term response to variation in weather and prey, or sampling error due to shifting of pairs outside of surveyed sites cannot be determined using the current monitoring study plan employed by the U.S. Forest Service. However, data from the CTNF reflects a pattern documented at other locations in the western U.S. that indicated a peak in the number of occupied goshawk nest sites in 1992 and a subsequent decline. It remains unknown if goshawk populations exhibit periodic cyclical highs in the western U.S. similar to those documented farther north (Doyle and Smith 2001) or if trend data indicates the onset of a more serious, longer-term decline related to habitat or climatic change. Because many goshawk studies and monitoring projects were initiated during or after the early 1990s, baseline data prior to 1992 are lacking from most areas. How to interpret recent trends since 1992 remains challenging.

Results of the current study emphasize the need to develop more comprehensive, well-funded, and statistically valid monitoring plans for goshawks that can track population trend, reproductive success, and habitat relationships in a timely and meaningful way. However, declines at known nesting areas measured since 1992 suggest that a conservative approach for managing remaining mature/old growth forests would be most prudent until our knowledge and understanding concerning the relationship between goshawk demographic parameters and loss of mature forest habitat increases (DeStefano 1998).

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